Product and hot rolling process development of NV40 steel plates[1]

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1. INTRODUCTION

The Companhia Siderúrgica Paulista – COSIPA is an integrated steel plant of the Usiminas System located in the municipality of Cubatão, in the coastal region of the São Paulo state, Brazil. This works produces 4.5 millions tons of steel per year; 1.0 million tons of this output are delivered as rolled plates, which meet a wide range of uses, such as those in agricultural implements, industrial machinery, pipelines, boilers and pressure vessels, building industry, shipbuilding and offshore platforms. COSIPA's Plate Mill line started up in 1978. This factory has two walking-beam slab reheating furnaces, one four-high reversible rougher mill that produce plates with maximum width of 4.100 mm, one shear line to cut plates with thickness up to 40 mm and gas cutting line to cut plates with thickness over 40 mm and one heat treatment line. The Usiminas System produces all plates used in the Brazilian shipbuilding industry and COSIPA works is responsible for 90% of this output.

The market of shipbuilding plates always was a very challenging one. The strong technological evolution of this market segment is requiring plates more and more lighter and stronger in order to minimize the costs associated with oil and natural gas exploration and transportation. In some cases this is the only way to make feasible the exploration of fossil fuel reserves in harsh environments. Cosipa steelworks was always a traditional supplier of flat products for the shipbuilding market, but as well has permanently to overcome hard challenges to maintain this position. Recently a Brazilian Government-sponsored program for renovation of the merchant ship fleet and construction of new offshore platforms was launched, imposing new performance requirements on plate steel, which prompted to a technological updating of the COSIPA's plate mill line. News equipments were installed, as a new gamma-ray hot gauge meter for a rigorous dimensional product control and a new automatic ultrasonic testing plate machine. Besides that, COSIPA launched a program for the development of new plate products with higher strength and toughness.

This paper shows the new rolling processes, as well mechanical and dimensional features of COSIPA plates for shipbuilding, with emphasis on the recent development of the NV40 grade. This product development enabled Cosipa to supply A40, D40 and E40 grades produced through thermomechanical and normalizing treatment.

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2. HOT ROLLING PROCESS DEVELOPMENT

The 40 kgf/mm² plate grade had to be developed at COSIPA as products with this strength grade were not made in Brazil before. This market required quick delivery of such new grades, so this new product was developed based in the results got from 36 kgf/mm² tensile strength plates in order to speed material development. Thermomechanical Processing (TMCP) and normalizing heat treatment were the process routes selected for this new plate product. Table I shows COSIPA certified process for the production of shipbuilding plates.

Standard		Certifying Institutions							Delivery Conditions
YS (kgf/mm^2)	Grade	ABS	BV	GL	KR	LR	NK	NV	
32, 36	A, D	•	•	•	•	•	•	•	AR, TMCP, N
	E	•	•	•	•	•	•	•	TMCP ou N
40	A, D							•	TMCP
	E							•	TMCP+N

Table 1 – Shipbuilding plate grades supplied by COSIPA, where AR means as rolled; TMCP, thermomechanical process; and N, normalizing.

Two alloy designs were used in the development of the grade 40 shipbuilding plate, respectively for each process route, TMCP and normalizing. Both were processed in ladle-furnace and submitted to desulfurizing and inclusion shape control treatments. Two heats of each alloy design were produced and hot rolled in plates with 25,40 and 50,80 mm thicknesses. Samples taken from these plates were submitted to tension, lamelar tearing, impact, and welding tests, as well metallographic analysis.

After the successful trials the full production of these plates began, fulfilling the needs of the shipbuilding market. The great challenge faced by COSIPA in the beginning of industrial production of this kind of product was to improve hot rolling process, allowing the production of 6.00 to 50.80 thickness plates. This market has some special delivery characteristics, like the need of plates with very large dimensional variations and exact number of pieces of the same plate grade. Another significative feature is the fact that, for some dimensional and strength combinations the number of plates to be produced is very small, requiring a stringent operational control.

The slabs of such steel grade were reheated under specific higher temperatures and soaking times in comparison with common plate steels. This is due to the fact that these new alloys contain niobium, vanadium and titanium, as well special mechanical strength requirements.

Specific hot rolling pass schedules were defined for each thickness-width combination. This standardization consisted in a modification of the controlled rolling process formerly used and which became unfeasible for the production of the NV40 steel grade due to the wide plate dimensional diversification.

The normal controlled rolling process consists of three steps, as schematically shown in figure 1. The first step is known as the roughing stage and is characterized by the application high strain degrees to the rolling stock; this is possible due to the high rolling temperature. The second step is known as the holding stage; at that time the rolling stock is only cooled at the roller table, without being submitted to hot rolling until its temperature reaches an ideal value to resume the forming process. That is, there is no hot rolling at all during this step. The third step consists in the finishing stage of the rolling stock, which now is under a lower temperature. As the hot strength is very high, the strain degree applied in each pass became very low.

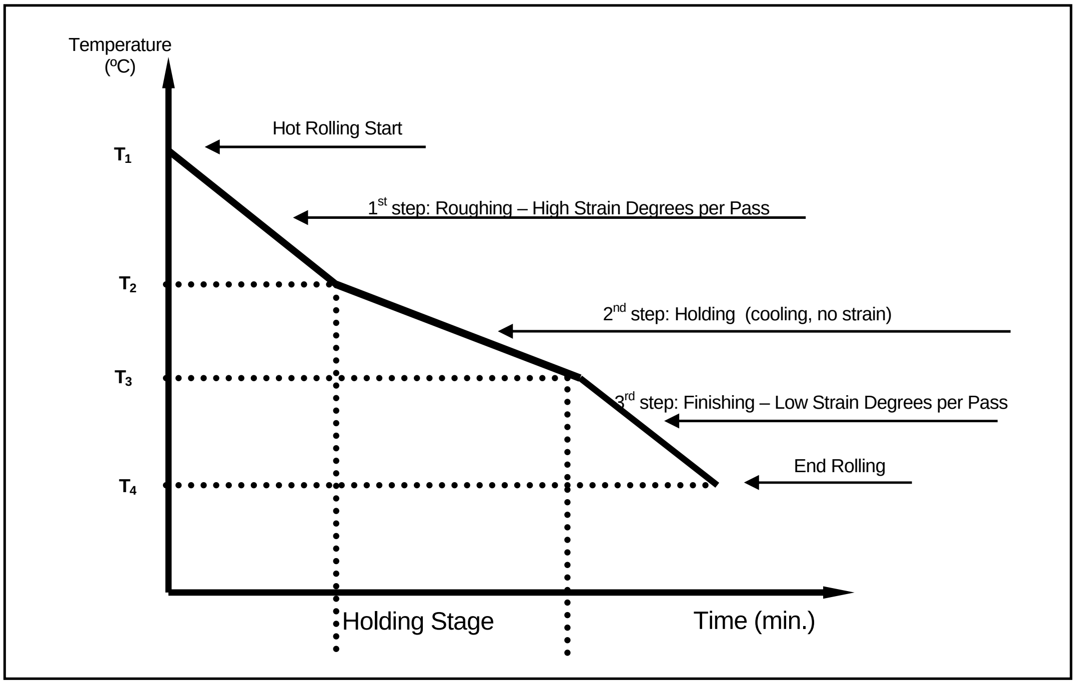

Figure 1 – Schematic View of the controlled roling process

During the holding stage of a rolling stock other slabs are roughened. This concomitant process, known as tandem rolling, increases the productivity of the plate mill line.

Formerly the rolling stock thickness after the first controlled rolling stage was defined accordingly to the final plate thickness. So, in most of the times there were rolling stocks with different thickness values awaiting finishing rolling during the tandem process. This variety of dimensions confused mill operators, which had more difficulties to achieve the correct thickness value for each plate in process. This eventually could compromise product quality. So it was proposed a modification in the rolling stock thickness after the roughing stage, which was fixed for a determined product thickness range. This new approach promoted a lower thickness variation after the roughing of the rolling stock and the operational control of the hot rolling process was easier. Figure 2 shows schematically the modification done in the ratio rolling stock thickness : product thickness.

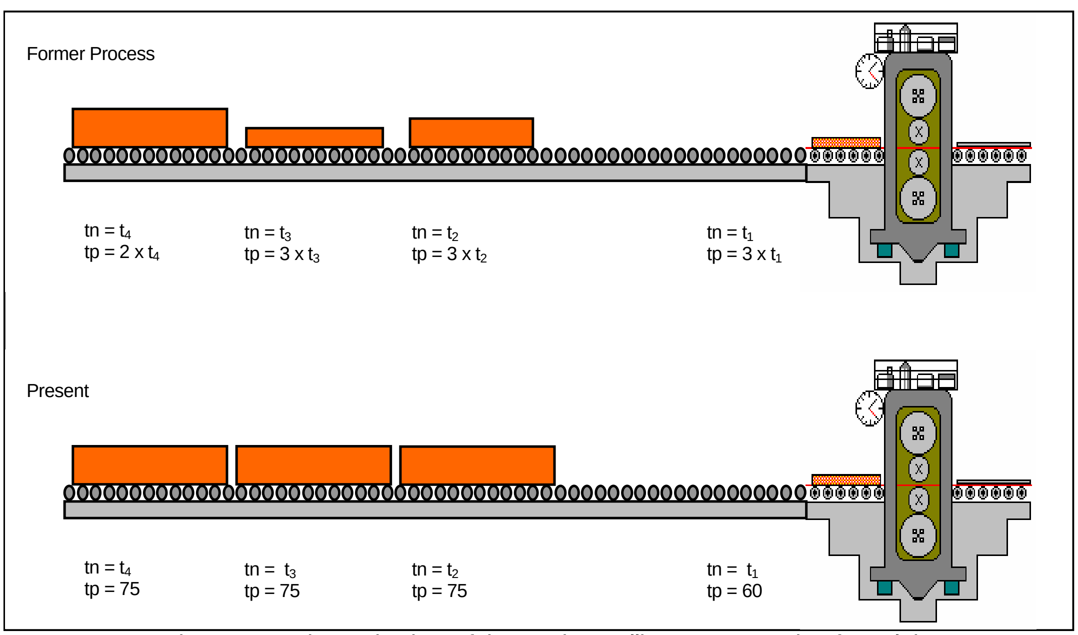

Figure 2 – Schematic view of the tandem rolling process using four slabs.

The definition of the standard holding stage thickness according to the thickness range of the final plate allowed the standardization of the finishing rolling stage, defining the number of rolling passes and strain per pass. This standardization allowed a better temperature evolution control and pass strain degree, yielding better quality products.

Plate grades with mechanical property requirements in the Z-axis (lamellar tearing) and E40 grade plates were also submitted to a normalizing heat treatment, because this process showed to be a more effective process route to achieve the required mechanical properties, particularly for thickness above 25,40 mm.

3. RESULTS AND DISCUSSIONS

From the conclusion of the development of the NV40 steel plate up to 2005 COSIPA has produced 45.600 tons of such product, as shown in figure 3.

The dimensions of the plates were:

- Thickness: 6.00 to 50.80 mm
- Width: 1,200 to 3,250 mm
- Length: 5,000 to 14,000 mm.

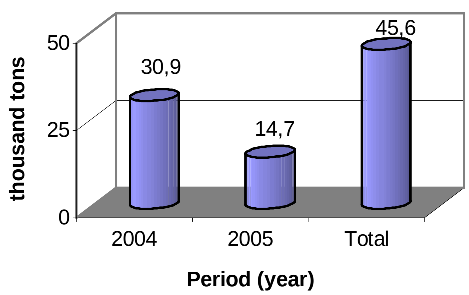

Figure 3: Total production of NV40 steel plate at COSIPA.

Most of this production corresponds to the A40 and D40 grades, which were produced through controlled rolling (TMCP) and represented 82,90% of the total amount of plates produced. The remaining 17,1% were distributed among the E40 grade and grades with lamellar tearing requirements, which where produced using the normalising heat treatment route, as shown in figure 4.

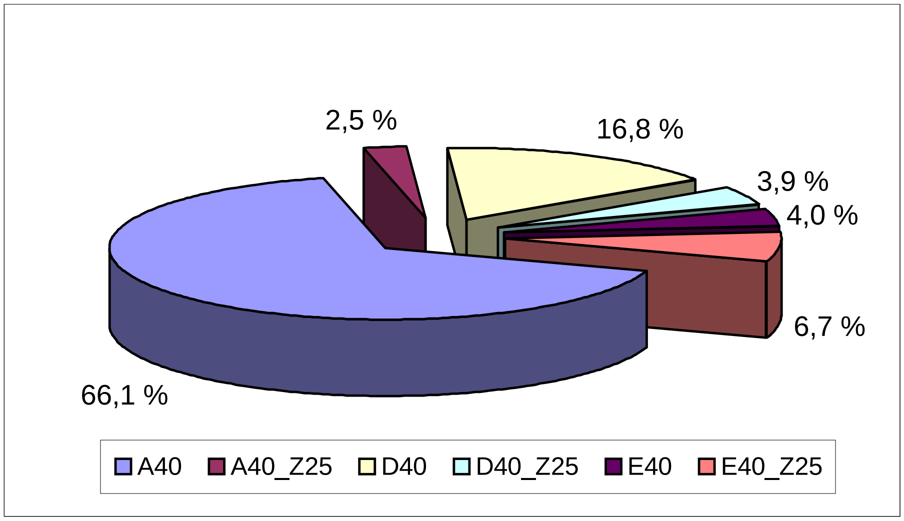

Figure 4: Relative distribution of plate grades in total NV40 steel plate production.

Another important factor to be considered are the relationship between theoretical weight (which is calculated from plate dimensions), steel density and real weight of the plates. This relationship should be controlled and it shows if plate dimensional variations are within the tolerated range. In the case of this batch of NV40 grade plate steel the mean value of this relationship is equal to 1.85%. Figure 5 shows plate thickness variation effectively got in relation to the nominal thickness. Even in the cause of the 8.0 mm gauge this variation was equal to 3.0%, a very good result when one considers that the standard allows a maximum value of 9.5%.

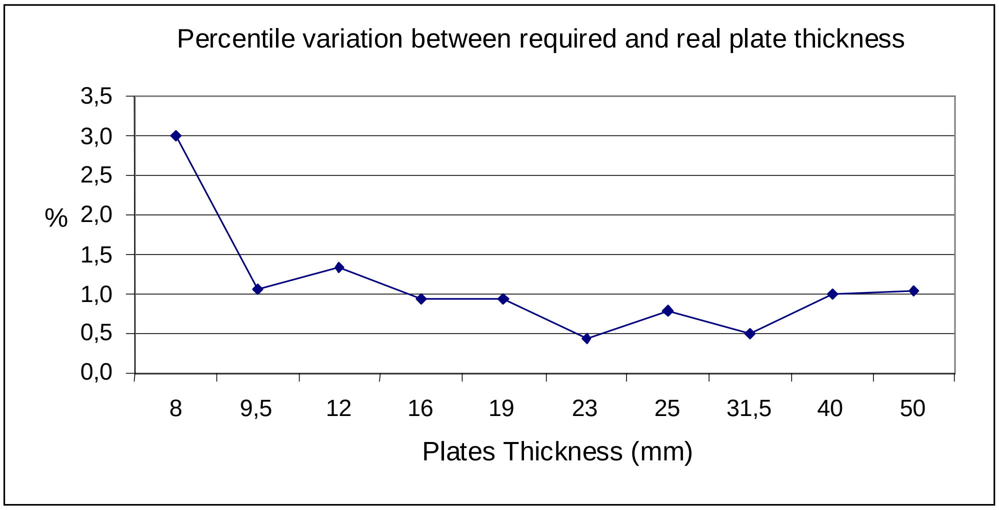

Figure 5: Percentile variation between required and real plate thickness.

The mean yield strength varied between 435 and 538 MPa, while mean tensile strength has ranged from 529 to 562 MPa – a great achievement compared with specified values. Mechanical strength produced through TMCP was inversely proportional to plate gauge. This result can be attributed not only to the greater total strain degree applied to the lower gauge plates, but also to the lower finishing temperature applied to these thinner products. Figure 6 shows the variation of mean values of yield and tensile strength with A40 and D40 grade plate thickness.

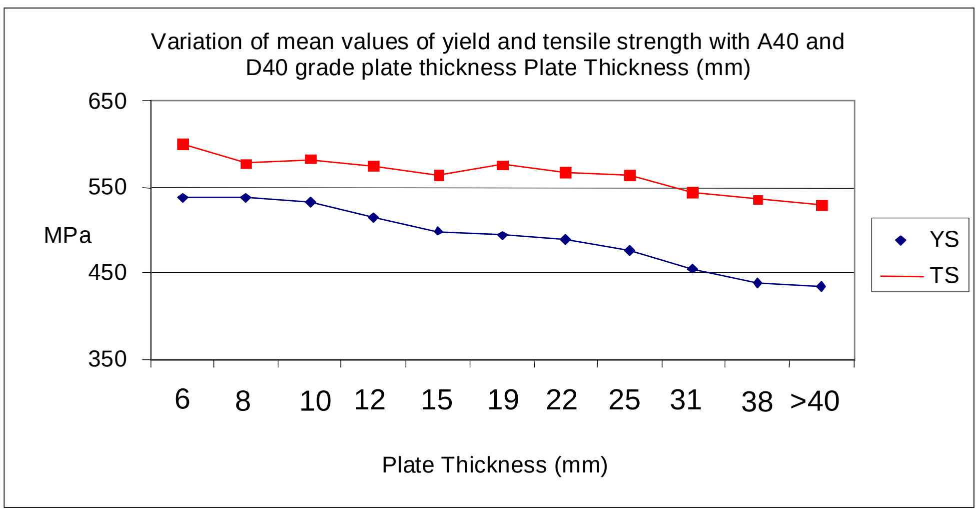

Figure 6: Variation of mean values of yield and tensile strength with A40 and D40 grade plate thickness.

The results got from the tensile tests of the E40 and lamelar tearing resistant steel plate grades were more constant because these grades have been produced through the normalising heat treatment route. Figure 7 shows these results.

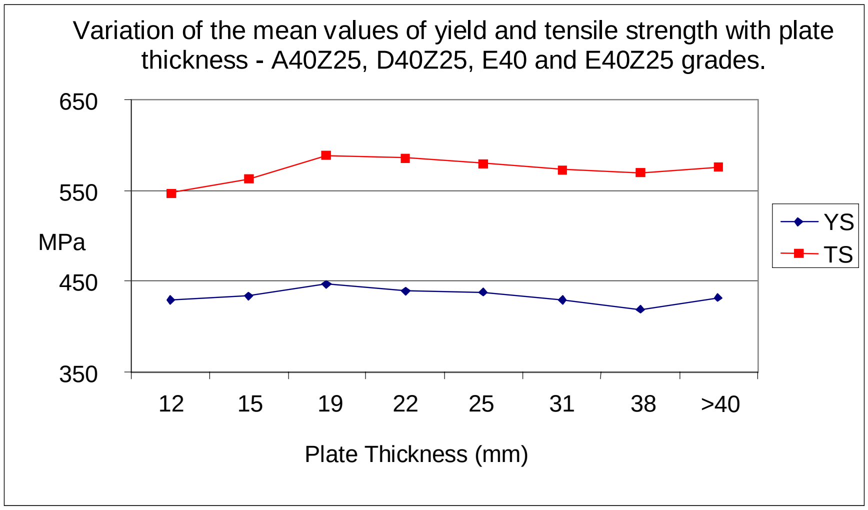

Figure 7: Variation of the mean values of yield and tensile strength with plate thickness, considering only the A40Z25, D40Z25, E40 and E40Z25 grades.

The values got from the Charpy impact tests were superior to 100 joules, a great performance when compared to the values specified by the plate product standards. These results are shown in figure 8.

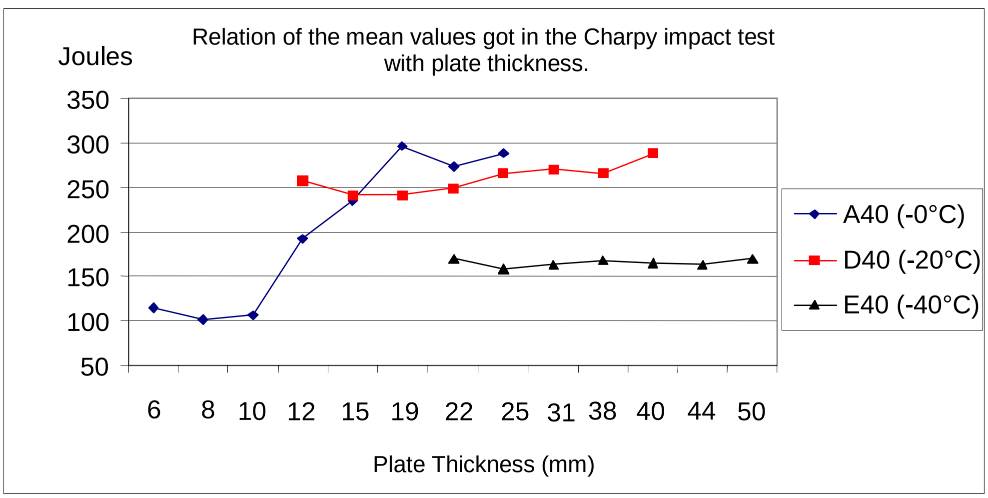

Figure 8 - Relation of the mean values got in the Charpy impact test with plate thickness.

4. CONCLUSIONS

The modifications implemented in the former controlled rolling process performed at COSIPA's plate mill provided a real improvement in plate final dimensions and a satisfactory value for the relationship between the calculated and real plate weight.

The development of new plate schedules allowed the operator to get a better operational control and standardization of the rolling process, yielding plates with more consistent mechanical properties. This process standardization will serve as a basis for the future automation of the plate rolling process.

The development of the NV40 steel plate product, along with the use of new equipments like the gamma ray hot thickness gauge and the automatic plate ultrasonic inspection machine, will consolidate COSIPA's position as a supplier of premium plates to the shipbuilding industry and to other customers that require quality excellence.